Fat Suppression in the Abdomen

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Introduction

Due to the different chemical environment, hydrogen nuclei in water- and in fat-tissue have different values for some MRI-relevant parameters, mainly being the relaxation time and the resonance frequency (chemical shift).
These differences can be used to selectively suppress/reduce the signal of fat bound protons.
Thus relaxation-dependant and chemical shift-dependant methods can be used for fat suppression.

Inversion Recovery (STIR = Short TI Inversion Recovery)

This technique is based on the different relaxation behavior of water- and fat tissue. Fat has a much shorter T1 relaxation time than other tissues.
Prior to the excitation pulse of the sequence an inversion pulse ($\alpha = 180°$) is applied which inverts the spins of all tissues. The tissues perform T1 relaxation.
By choosing TI such that the longitudinal magnetization of fat at that time is zero, fat spins will not contribute to the MR signal.

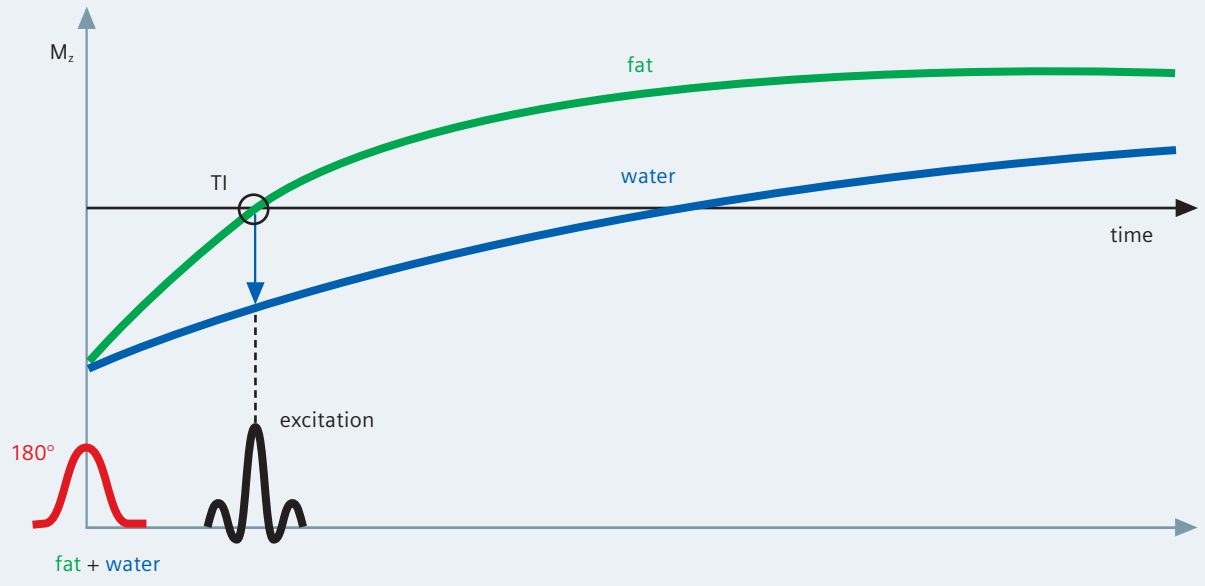
STIR images have an inverted T1 contrast: Tissue with long T1 appears brighter than tissue with short T1.

Advantages:
- Insensitive to B_0 inhomogeneities.

Disadvantages:
- Additional inversion pulse increases minimal TR and total measurement time or reduces maximum number of slices.
- Tissue contrast is affected.

Applications:
Detection of metastasis in the abdominal region.

1



1 Short TI Inversion Recovery (STIR).

SPAIR technique (SPAIR = Spectrally Adiabatic Inversion Recovery)

SPAIR is an alternative to the conventional methods spectral fat saturation or water excitation.

A spectrally selective adiabatic inversion pulse excites only fat spins, thus no STIR like contrast is created. With gradient spoiling the transverse magnetization is destroyed.

The inversion time TI_{null} is such that the longitudinal magnetization of fat at that time is zero, so fat spins will not contribute to the MR signal.

SPAIR Mode: Strong/Weak is available for SE-type sequences.

Advantages:

- Insensitive to B_1 inhomogeneity.
- Tissue contrast is not affected.
- Quick FatSat can be applied for increased performance (VIBE).

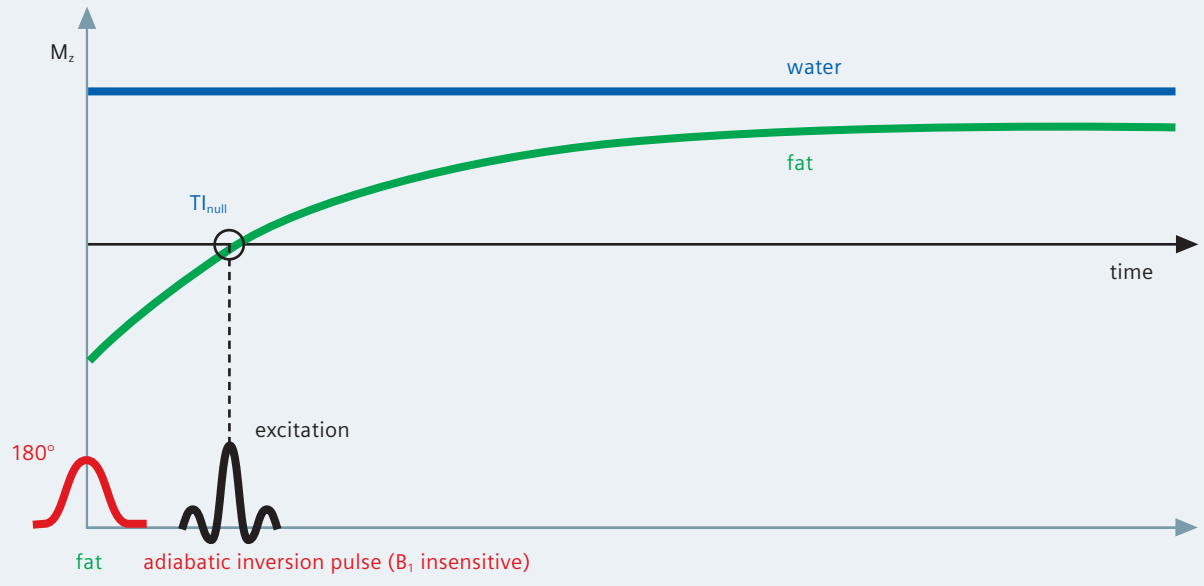
Disadvantages:

- Increased minimal TR or reduced maximal number of slices due to more complex preparation pulse (partially compensated by Quick FatSat).
- Slightly reduces the overall signal intensity in single shot sequences (*syngo* REVEAL).

Applications:

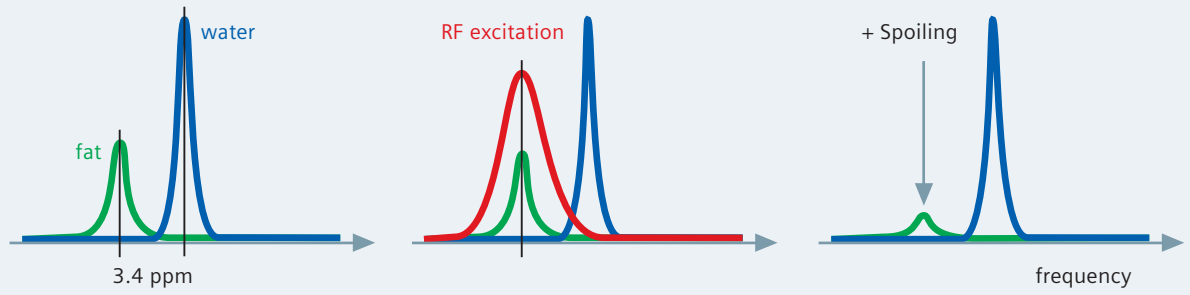
- Abdominal breath-hold applications with TSE, SPACE, HASTE, VIBE.
- Fast T1-weighted applications in breath-hold based on the VIBE sequence (with proper setting of the parameter "Lines per shot").

2



2 Spectrally Adiabatic Inversion Recovery (SPAIR).

3



3 Spectral fat saturation.

Spectral Fat Saturation

This technique is based on the chemical shift (3.4 ppm) i.e. the difference in resonance frequencies between fat- and water-bound protons.
Applying a narrow band frequency selective RF pulse, mainly fat-bound protons are excited. This transversal magnetization is destroyed afterwards by spoiler gradients, thus no fat magnetization is left for imaging.

Setting *Quick FatSat* not every slice excitation is preceded by a preparation pulse, thus:
- a shorter TR possible
- breath-hold examinations possible (e.g. VIBE, recommended 40 lines/shot)

Two *FatSat Mode's (strong/weak)* are available.

Advantages:
- Tissue contrast is not affected.
- Quick FatSat can be applied for increased performance.

Disadvantages:
- Sensitive to B_0 and B_1 inhomogeneities.
- Additional preparation pulse increases minimal TR and total measurement time or reduces maximum number of slices (partially compensated by Quick FatSat).

Applications:
- T2-weighted abdominal applications with Fat Saturation based on the sequences TSE, HASTE and SPACE.
- Fast T1-weighted applications in breath-hold with Quick FatSat based on the sequences FLASH-2D and VIBE.

Water Excitation

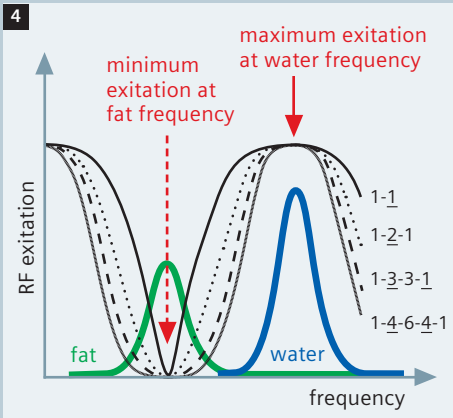
This technique is based on the chemical shift i.e. the difference in resonance frequencies between fat- and water-bound protons.
No additional preparation pulse is necessary, instead a special excitation pulse (binomial pulse) is used with the spectral excitation profile as shown below (minimum excitation of fat bound protons, maximum excitation of water-bound protons):

Advantages:
- Insensitive B_1 inhomogeneities.

Disadvantages:
- Increased min TE, TR and total measurement time or reduced maximum number of slices.

Applications:
- Frequently used on low field systems where spectral fat suppression is inapplicable.
- Axial TurboFLASH applications with breath-hold or PACE (**P**rospective **A**cquisition **C**orr**E**ction) free breathing.
- *syngo* REVEAL applications in breath-hold technique.

4



4 Water Excitation.

Dixon Technique

The Dixon technique is based on the chemical shift i.e. the difference in resonance frequencies between fat- and water-bound protons. With this technique two images are acquired. In the first image the signal from fat-protons and from water-protons are "in phase", in the second they are "opposed phase". By additional computations a separate fat- and water-image can be calculated. The Dixon method is integrated into the VIBE sequence.

Dixon delivers up to 4 contrasts in one measurement: in-phase, opposed-phase, water and fat images.

Advantages:

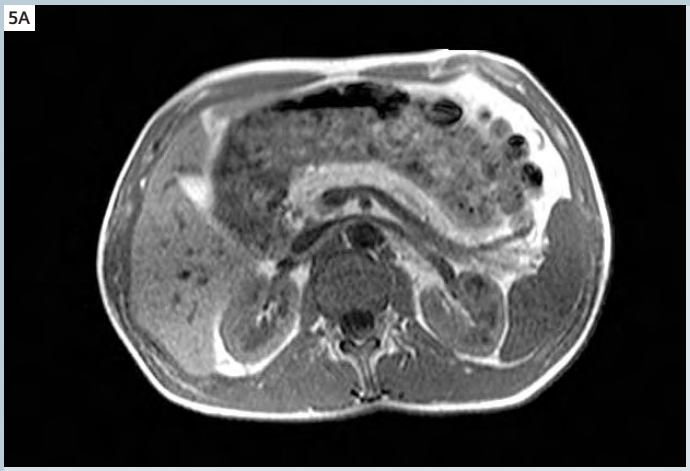
- Insensitive to B_0 and B_1 inhomogeneities.
- 4 contrasts delivered in one measurement.

Disadvantages:

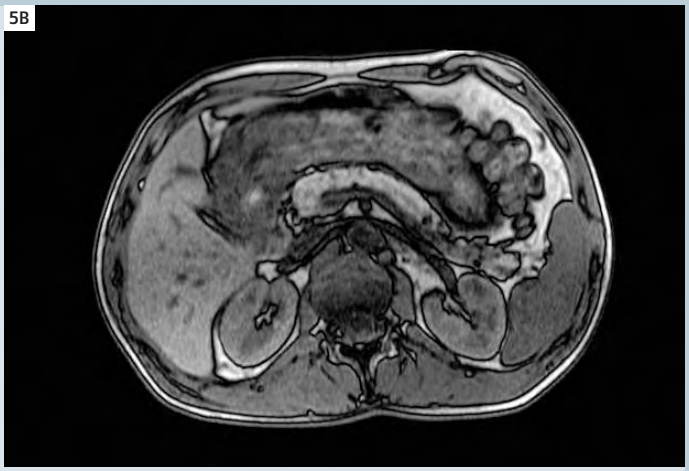
- Increases minimal TR because in- and opposed phase data must be acquired (partially compensated by using integrated Parallel Acquisition Techniques (iPAT)).

Applications:

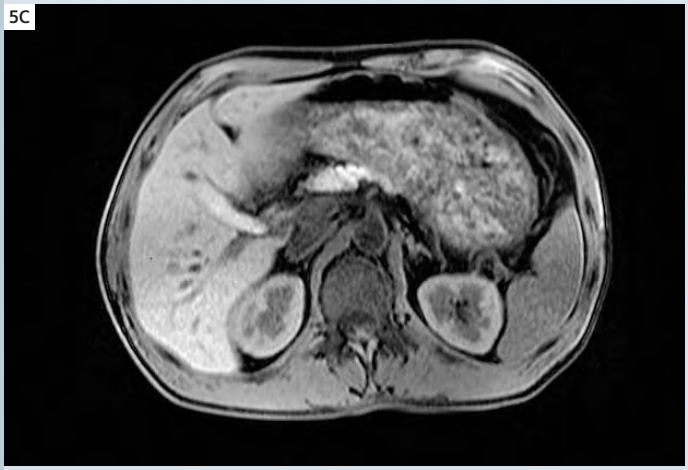
- Robust fat / water imaging in abdominal applications.
- Fat quantification measurements.



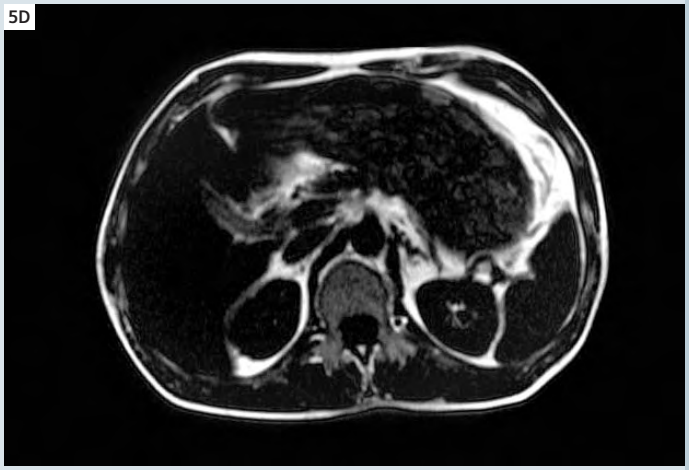
5A In-phase image.



5B Opposed-phase image.



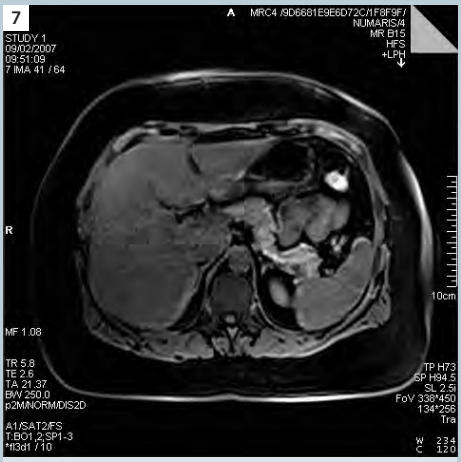
5C Water image.



5D Fat image.

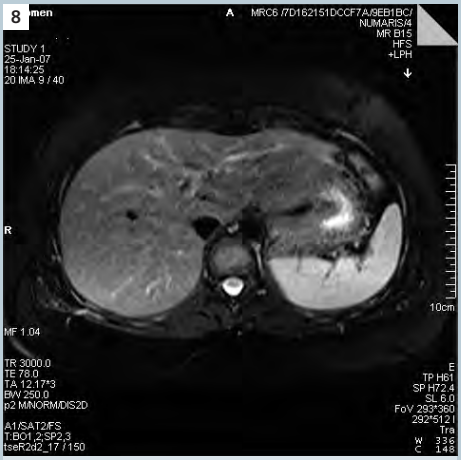
STIR-Example

6 STIR PACE free breathing.



7 T1-weigthed VIBE
Quick FatSat with breathhold.

Water Exitation Examples



8 T2-weighted TSE SPAIR
with multi-breathhold.

9 T1-weighted VIBE SPAIR breathhold.

10 T1-weighted TurboFLASH
with Water Excitation
and PACE free breathing.

Overview: Sequences used in abdominal imaging with recommended fat/water selective techniques

	FatSat		SPAIR		STIR	Water Exitation	Dixon
	std	**Mode: strong/weak**	**std**	**Mode: weak/strong**			
TSE/SE	✓	✓	✓	✓	✓	–	–
HASTE	✓	✓	✓	✓	✓	–	–
SPACE	✓	✓	✓	✓	✓	–	–
FLASH-2D	✓ *	✓ **	–	–	–	–	–
VIBE	✓ ***	–	✓ ****	–	–	✓	✓
Reveal	✓	–	✓	–	✓	✓	–
TurboFLASH	–	–	–	–	–	✓	–
TrueFISP	✓	–	–	–	–	✓	

*both FatSat and Quick FatSat available, **only with Quick FatSat, ***with Quick FatSat "Lines per shot" are selectable, **** "Lines per shot" are selectable

Overview: Advantages / Disadvantages of different Fat Suppression techniques

	FatSat	SPAIR	STIR	Water Exitation	Dixon
Insensitive to B_1 inhomogeneities	✓	✓	–	✓	✓
Insensitive to B_0 inhomogeneities	✓	–	✓	–	✓
High performance (quick mode)	✓	✓	–	–	–
Multiple contrasts generated	–	–	–	–	✓
Timing changes	TR, TA	TR, TA	TR, TA	TE, TR	TR
Contrast not affected	✓	✓	✓	✓	✓